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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 72.

B. T. GALLOWAY, *Chief of Bureau.*

MISCELLANEOUS PAPERS.

I. CULTIVATION OF WHEAT IN PERMANENT ALFALFA FIELDS.

By DAVID FAIRCHILD, *Agricultural Explorer.*

II. THE SALT WATER LIMITS OF WILD RICE.

By CARL S. SCOFIELD, *Botanist, Grain Grade Investigations.*

III. EXTERMINATION OF JOHNSON GRASS.

By W. J. SPILLMAN, *Agrostologist.*

IV. INOCULATION OF SOIL WITH NITROGEN-FIXING BACTERIA.

By A. F. WOODS, *Acting Chief of Bureau.*

Issued June 24, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY,
Pathologist and Physiologist, and Chief of Bureau.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.
ALBERT F. WOODS, *Pathologist and Physiologist in Charge,*
Acting Chief of Bureau in Absence of Chief.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.
FREDERICK V. COVILLE, *Botanist in Charge.*

GRASS AND FORAGE PLANT INVESTIGATIONS.
W. J. SPILLMAN, *Agrostologist in Charge.*

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SEED AND PLANT INTRODUCTION AND DISTRIBUTION.
A. J. PIETERS, *Botanist in Charge.*

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EXPERIMENTAL GARDENS AND GROUNDS.
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[a] The four papers constituting this Bulletin were issued in separate form on December 9, 1904, January 25, May 20, and May 25, 1905, respectively.

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MISCELLANEOUS PAPERS.

B. P. I.—130. S. P. I. D.—41.

I.—CULTIVATION OF WHEAT IN PERMANENT ALFALFA FIELDS.[a]

By David Fairchild, *Agricultural Explorer, Seed and Plant Introduction and Distribution.*

Wheat and alfalfa are being successfully grown together at the same time on the dry uplands of North Africa. Alfalfa, although doubtless one of the greatest forage crops in the world, has not so far in America been capable of utilization in a short rotation with wheat, but the recent experiments of a Swiss agriculturist in Algeria have proved that wheat and alfalfa can be grown to decided advantage in alternate rows.

During an exploring trip which the writer made for the Office of Seed and Plant Introduction and Distribution, in company with Mr. C. S. Scofield, a visit was made to Sétif, Algeria, where Mr. G. Ryf, in charge of the Swiss settlement there, has some remarkable experi-

[a]Alfalfa is probably the greatest fodder crop now grown in America, and wheat still holds its place as one of our most important cultures. The immense areas of wheat land in the Northwest, and the spread of durum wheat cultivation into the arid Southwest, where alfalfa is the principal fodder crop, should make unusually interesting the experiment of Mr. Ryf as reported in this paper by Mr. Fairchild.

With the present increasing interest in dry-land farming in portions of the West, notably in Utah and Montana, the present paper is very timely, and measures should by all means be taken to give the method a proper trial.

The observations of which this is a report were made by Mr. Fairchild and Mr. C. S. Scofield during their explorations in Algeria in 1901, but at that time the experiments of Mr. Ryf had not progressed far enough to merit calling them to the attention of American cultivators.

A. J. Pieters, *Botanist in Charge.*

Office of Seed and Plant Introduction and Distribution,
Washington, D. C., November 19, 1904.

mental grounds. We noted, among the numerous interesting things with which Mr. Ryf was experimenting, a field of alfalfa planted in rows 3 feet apart, between which rows, he assured us, he grew every other year a crop of durum wheat. Since making this observation in Algeria in 1901, the attention of the writer has been called to the fact that such a rotation, if it can strictly be called a rotation, is not practiced in regions in America which are similar to the dry uplands of western Algeria so far as climate and soil are concerned, and it has seemed worth while to describe this simple method which Mr. Ryf has discovered and which he has now in satisfactory operation on his place.

In response to a letter of inquiry, the writer received a communication from Mr. Ryf, dated August 12, 1904, of which a free translation from the French follows:

I believe more and more firmly that lucern[a] is destined to play an important rôle in all dry countries where forage is scarce. The value of the intercalary culture of cereals in lucern has been proved. I believe it to be rational and to solve the great problem of an economical manure crop. After numerous trials with planting lucern in rows at different distances apart, we have at last found that a distance of about 40 inches between double rows of the plant is most satisfactory. The distance between the single rows is uniformly about 4 inches. Formerly we sowed the lucern in single rows, but we have found it surer to sow it in double rows. With good seeders the work of sowing is not difficult. The space of 40 inches between the double rows of lucern we sow ordinarily with only three rows of wheat or other cereal, each row occupying about 7 inches and the double row of lucern 12 inches, making a total of 40 inches. The space between the two rows of lucern is cultivated two or three times. In one of these cultivations the earth is turned toward the rows of lucern; in the other, away from them. After each cultivation a harrow (and sometimes a roller) is run over the ground, providing there are stones or large clods. These spaces between the rows of lucern are sown only one year out of every two, the yield in forage during the year in which the ground is left fallow compensating largely for the loss which is incurred by not planting the ground. In very good soils our good indigenous varieties of lucern make such a growth that the rows join one another, notwithstanding the considerable distance of nearly 40 inches which separates them. A field during the fallow period looks as if it had been sown broadcast, or at least drilled in lines very close together. We get thus, on dry soil, without irrigation, two or three cuttings of lucern, and pasturage more or less abundant during the remainder of the year. We feared that lucern might injure the cereals planted between the rows, but there has been no reason for this fear. I would add that at the time of the plowing preparatory to sowing the ground we take pains to cut off with the colter and plowshare, both of which are kept well sharpened, masses of the lucern roots. This operation in a measure checks the growth of the latter during the vegetative period of the cereals, but being a plant of vigorous spreading habits it soon sends out new roots and shoots in such a way that the following year it has regained all of its former vigor.

There are very considerable advantages in this method of culture. The

[a] The French name *luzerne* is applied in Algeria, as elsewhere, to *Medicago sativa* Linn., which in America is called alfalfa.

lucern sends its roots from 1 to 3 meters (3.28 to 9.84 feet) deep into the subsoil and draws from it the water necessary for its growth. It absorbs, as well, nitrogen from the atmosphere, which is the other source of food. From the roots, which are amputated periodically, is secured a green fertilizer which, according to numerous experiments, is equivalent to a good dressing of barnyard manure. But this manure, in the form of amputated roots, plays still another rôle quite as important in dry land. It serves the purpose of a water reservoir. In fact, these roots in decomposing become like little sponges which run through the soil, and in these the rain water accumulates. These roots, penetrating deeply, thus constitute reservoirs of humidity, at the same time breaking up and rotting in the soil and subsoil, in this way furnishing nourishment and moisture to the cereals which are grown between the rows, and playing the rôle of excavator at the same time.

Our indigenous varieties of lucern, which have been acclimated in this region since Roman times, are incomparably more valuable than the cultivated lucern called *de Provence* or *de Poitou*. The former varieties are as strong and hardy as the latter are exacting and delicate, and they will last for several centuries, if not always, defending themselves victoriously against the weeds, which they often kill in place of being killed by them. Among these indigenous species there is one which is in all respects superior, and we are doing our best to propagate this.

A number of cultivators have adopted the intercalary culture of lucern and cereals. One proprietor in Tunis wrote me recently that he was going to try 50 hectares (123.55 acres) of this intercalary culture. As for myself, I extend my cultures each year, and expect to sow next spring as large an area as the seed selected will permit. A severe storm on July 13 destroyed a large part of my lucern which had been cut for seed, which fact I regret exceedingly. I believe that our indigenous lucerns would grow in Montana and other of your cold and dry regions, but under these conditions there are certain precautions to be taken in order to bring the young plants to maturity. Once well established, no freezes would destroy them; of this I am convinced. Our climate on the high plateau of Algeria, although not so cold in winter, resembles singularly that of the dry States in the central and western portions of your country.

Whether or not a place for this unusual method of cultivation can be found in the drier regions of this country is well worth finding out, in view of the fact that so successful an experimenter and so practical a farmer as Mr. Ryf has pronounced it a commercial success in Algeria after several years of trial.

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II.—THE SALT WATER LIMITS OF WILD RICE.[a]

By Carl S. Scofield, *Botanist in Charge of Grain Grade Investigations; Botanical Investigations and Experiments.*

INTRODUCTION.

Wild rice (*Zizania aquatica* L.) is naturally a fresh-water plant, and its growth along the Atlantic coast of the United States is confined for the most part to sluggish streams or to those deep estuaries that are diluted by a large amount of fresh water. There are in many of these streams and estuaries large areas of marsh lands or mud flats that are submerged and exposed alternately by the tide. Wherever the water is sufficiently fresh, such conditions are almost ideal for its growth, and in many places large wild rice fields now exist, but there are still other places of similar nature where the plant is not found and where attempts to establish it have been made without success. These failures have been ascribed usually to the poor quality of the seed used in planting, and probably this has been one of the important causes.

An investigation undertaken two years ago,[b] in cooperation with

[a] Wild rice is one of the favorite foods of wild ducks and other game birds in the eastern United States, and owners of shooting preserves often desire to plant it in order to increase the richness of their feeding grounds and thereby attract larger numbers of birds. Plantings heretofore made have often proved failures, particularly in brackish waters along the seacoast. The causes of failure under these circumstances have been two—the use of seed which had been so dried in the curing process as to destroy its vitality, and an excess of salt in the water, by reason of which either the seeds or the young plants were killed. A method of harvesting and curing which would insure vitality in wild rice seed has already been described in Bulletin No. 50 of the Bureau of Plant Industry. In the present paper are recorded the results of an inquiry into the degree of salinity which the plants will withstand. This information will make it possible to ascertain in advance, by a determination of the salinity of a particular body of water, whether wild rice planting can or can not succeed.

Frederick V. Coville, *Botanist.*

Office of Botanical Investigations and Experiments,

Washington, D. C., November 30, 1904.

[b] See Bulletin No. 50 of the Bureau of Plant Industry, "Wild Rice: Its Uses and Propagation."

the Seed Laboratory of this Department, demonstrated the fact that wild rice seed should never become dry if its vitality is to be preserved. It was also shown that this seed can be gathered and stored over winter, if need be, provided it is kept in water that is very cold, and well aerated or frequently changed, or even frozen.

From numerous letters received during the year from various points along the coast, it has become evident that not all previous failures were due to the lack of vitality of the seed. It has been a well-recognized fact that wild rice will not grow in salt water; that is, in water as salt as that of the ocean, but just what its salt water limits are seems never to have been determined, or at least no definite information on this point is available. It was obvious from the nature of the inquiries received that some such information was needed, and consequently some investigations have been made near Washington, where wild rice grows along streams flowing into Chesapeake Bay. Three separate regions were examined, and two of these gave excellent opportunities for determining the salt water limits of the plant.

As wild rice is a thoroughly aquatic plant—that is, grows on soil entirely submerged for at least a part of the day during its period of growth—the tests for salinity were confined to the water surrounding the plants. The difficulties attendant upon determining the quantity of water involved in cases of soil samples threatened to complicate the investigation without adding materially to the results desired.

THE METHOD OF TESTING SALINITY.

The salt content of the water was determined by means of an electrolytic bridge designed by Dr. Lyman J. Briggs, of the Bureau of Soils of this Department, and such as is now in general use by that Bureau. The principle involved in the use of this instrument is that with a given temperature the electrical conductivity of the water increases with the amount of salt in solution, or, conversely, the electrical resistance of the water decreases as its salinity increases. The instrument is compact, portable, and simple of operation and gives results that are accurate to a high degree and capable of almost direct reading. All the difficulties involved in securing a large number of samples and making numerous laboratory analyses are, therefore, obviated and a survey of any locality may be made and the salt content of the water determined on the spot, where such information is of the greatest value in interpreting the distribution of the plants studied.

The regions surveyed were visited by boat and the water was examined both where the wild rice grew vigorously and where its growth was obviously inhibited by the excessive salt content of the water. A special form of cell, designed by Doctor Briggs for use in testing irri-

gation water, was found best adapted to this work. This cell consists of two platinum terminals, coated with platinum black, and protected by a perforated hard-rubber bulb. The cell is attached to the bridge by insulated leads and immersed in the water to be tested. The bridge readings are given in ohms, and a calibration by measuring the resistance of solutions of known concentration suffices to transfer these readings into the scale of percentages by weight or parts of a normal solution, as desired.

In the following notes the instrument readings are used largely, while in the accompanying table the relations of those readings to both the percentage scale and parts of a normal solution are given.

THE REGIONS INVESTIGATED.

The first region investigated was that of the Potomac River between the city of Washington and Chesapeake Bay. Wild rice was reported as abundant in the deep inlets, or so-called rivers, penetrating both shores of the Potomac near its mouth. It was found, however, that these inlets receive so little fresh water in proportion to their size that the water in them is approximately as salty as that of Chesapeake Bay, and they contained no wild rice. There were, however, many clusters and even small fields of salt reed grass (*Spartina polystachya* (Michx.) Ell.) and also of the narrow panicum (*Panicum digitarioides* Carpenter) that may possibly have been mistaken for Zizania by casual observation from a distance.

There was some wild rice growing along the shores of the Potomac River below Washington as far down as Widewater, Va., near which point the water becomes salty; but the growth was so scattering and so obviously influenced by factors other than the salinity of the water that no opportunity was found to test the limiting conditions with respect to this factor.

The second region investigated was at the head of a deep inlet from Chesapeake Bay, northeast of Baltimore, Md. This inlet is known as the Gunpowder River. It receives fresh water from two small streams known as the Gunpowder Falls and the Little Gunpowder. These streams annually carry out and deposit in the head of the inlet large quantities of mud, through which several narrow channels are kept open by the current. The mud flats thus formed are submerged to the depth of a foot or more at flood tide and exposed by several inches at low tide.

This annual mud deposit is gradually filling up the inlet, and over the land thus made the progress of vegetation is to be seen in well-marked stages. The first plant to appear is pickerel weed (*Pontederia cordata* L.). These usually grow on the freshly deposited mud and doubtless aid greatly in holding it in place. These plants are followed by wild rice in isolated clusters which give seed enough to

produce a dense and luxuriant growth the year following. Meanwhile additional deposits of silt, together with the débris from the large stems of the wild rice plants, have transformed these soft mud flats into firm land, and the wild rice is gradually replaced by cattails (*Typha latifolia* L.) and various species of sedges and grasses.

The combined volume of the two streams above mentioned is sufficient to dilute the otherwise salty water of the Gunpowder River for a considerable distance out over the mud flats, and, so far as could be ascertained by careful observation, all other conditions are sufficiently uniform so that the spread of the wild rice into the river is limited only by the salinity of the water. In other words, conditions at the head of the Gunpowder River appear to be such that the salt water limits of the particular variety of wild rice growing there can be definitely measured.

There is, of course, the universal complication of tide movement, with the result that the concentration varies at any point in the critical zone as the tide alternately rises and falls. While the measurements of salinity were not continued at a given point in this zone throughout a complete cycle of tide movement, they were made for a sufficiently long period to give an approximate idea of the range of concentration.

The conformation of the mud flats and channels at this point is such that there is very little actual inflow of tide water over the rice fields. The incoming tide is little more than sufficient to stop the outflowing fresh water, even in the open channels, so that the concentration at any point within the wild rice field is practically the same at flood tide as when the tide has more than half run out.

At the mouths of the two streams mentioned, the Gunpowder Falls and the Little Gunpowder, the water at the beginning of ebb tide gave about 1,400 ohms resistance. (See table, p. 14.) Out beyond this point were the large fields of wild rice cut by open channels. Among the most luxuriant growth of wild rice, where the water was practically stagnant, the resistance was about 300 ohms, varying from 275 to 325 ohms at different points.

On the outer edge of the wild rice field and in the channels near this edge at flood tide the resistance was 150 ohms or less, while the open water outside of the field gave a resistance as low as 125 ohms. This latter reading corresponds to a 0.03 normal solution of sodium chlorid, and at this point evidently marked the limits of the resistance of wild rice to salt water.

The third region investigated was the Patuxent River in Maryland, from Chesapeake Bay to the head of navigation, which is Leon's Landing, a point just north of where the Chesapeake Beach Railroad crosses this river.

The Patuxent River, for a considerable distance above its mouth, is very wide in proportion to the volume of water it contributes to Chesapeake Bay, so that it does not form the conventional delta. As a result the tide is very pronounced as the stream narrows to the proportions necessary to deliver its water, and the line between fresh and salt water shifts for a long distance with each tide.

This action of the large tide movement considerably complicated the task of measuring the concentration of the water with which the plants along the stream are actually surrounded. It was found, however, that the wild rice plants, especially those along the lower part of the river, where the salt content was fairly high, are so situated that they have a minimum of actual water movement past them. In other words, where the conditions are such that the salt content of the river water at high tide is considerably greater than that to which the wild rice is accustomed, the plants along this portion of the stream were surrounded by water considerably fresher than that of the stream itself. The maximum concentration in which wild rice plants were found extensively growing in the lower river was about 0.03 of a normal solution of sodium chlorid, equivalent to a resistance of 125 ohms. Occasional plants were found, however, where the resistance was as low as 60 ohms, but these were so situated that they were doubtless surrounded a large part of the time by water much fresher than this. This latter test was made shortly after high tide and the plants were found in a little cove of slack water. It is probable this represents nearly the maximum concentration to which the plants were exposed.

A careful survey of the river below this point, White's Landing, failed to show any quantity of wild rice. There were occasional plants farther down the river, but always in situations well inland, that were probably fed by springs, so that the water of the overflow was considerably diluted. From White's Landing on up the river the concentration of the water diminished rapidly and the mud flats on either shore produced an abundance of wild rice. In fact, from Nottingham north to the head of navigation, wild rice is the most conspicuous feature of the vegetation bordering the river.

CONCLUSIONS.

From the surveys thus made in the vicinity of Washington, it seems fair to assume that the salt water limit of wild rice is approximately represented by 0.03 of the normal solution of sodium chlorid. This is very considerably less than the concentration of the water of Chesapeake Bay, which has a resistance of about 20 ohms, or a concentration equivalent to about 0.28 of a normal solution of sodium chlorid. It is also obvious that this represents about the maximum salt water

resistance of the species in the regions examined, since the growth along the limiting zone is abundant, and in the nature of the case the whole tendency is toward the selection of plants able to resist higher concentrations. The streams along which these plants grow on the Atlantic coast usually flow into salt water. Nearly all of them carry down large deposits of mud and form shallow deltas which give physical conditions best adapted to the plant, and any individuals able to succeed in saltier water would considerably aid the species in its conquest of territory.

When, therefore, the question of establishing cultures of wild rice along the coast streams is being considered, it is highly important that the concentration of the water covering these areas be determined, for this appears to be the factor of the greatest importance in ascertaining the possibility of establishing such cultures.

It may also be added that the salt water limits of wild rice may be determined approximately by the simple test of taste. When water is appreciably salty to the taste, it is too salty for the successful growth of this plant.

Table showing the relation between the readings of the testing cell used in the above surveys and the parts of a normal, and the percentage by weight solutions of sodium chlorid; also the relation of these concentrations to the growth of wild rice.

Resistance of water in cell at 80° F.	Parts of a normal solution of NaCl.	Percentage solution of NaCl.	Notes
Ohms.			
20	0.2800	1.6380	Concentration of Chesapeake Bay; no wild rice.[a]
60	0.0640	0.3740	Limit of occasional plants; excessive for successful growth.
125	0.0300	0.1755	Limit of wild rice growth; slight taste of salt in water.
250	0.0140	0.0820	Luxuriant growth of wild rice; no taste of salt in water.
1,400	0.0027	0.0158	Water at the mouth of Gunpowder Falls; abundant wild rice.
3,700	0.0010	0.0058	Water of the upper Patuxent and Potomac rivers; abundant wild rice.

[a] According to this test the water of Chesapeake Bay is considerably fresher than that of the Atlantic Ocean. Makin (Chemical News, 77: 155 and 171) finds that ocean water contains 3.631 per cent of solids, with the more abundant salts in the following proportions: NaCl, 76.915 per cent; $MgCl_2$, 11.407 per cent; $MgSO_4$, 4.483 per cent; $CaSO_4$, 4.226 per cent; K_2SO_4, 2.468 per cent.

III.—EXTERMINATION OF JOHNSON GRASS.[a]

By W. J. Spillman, *Agrostologist in Charge of Grass and Forage Plant Investigations.*

INTRODUCTION.

On account of the importance of the subject to the farmers of the South, the following notes, giving results of certain tests of methods of exterminating Johnson grass, are published in advance of the completion of the experiments undertaken. The complete investigations include not only a test of various cultural methods for the extermination of this pest, but also the use of various chemical preparations for this purpose, including such materials as crude petroleum (which is obtainable at very low prices in parts of the Johnson grass country) and various mixtures containing arsenic. The complete success of some of the cultural methods used in the experiments renders it important that they should be made available to the public at once. These methods are practicable on cultivated land, but do not apply to fence rows, ditch banks, or railway rights of way. It is hoped that effective methods of controlling or even of eradicating Johnson grass in the latter situations may also be developed.

The cultural tests here reported were conducted by the writer on the farm of Mr. J. B. Gay, of Columbus, Tex., and acknowledgment is made of the very faithful manner in which Mr. Gay has carried out instructions in connection with the conduct of the experiments. Three somewhat different methods of handling the soil were tested. The preliminary treatment of the soil was the same in each case,

[a] Johnson grass is probably the most troublesome weed in the Southern States. In the autumn of 1902 investigations were begun with a view to devising practical means of eradicating it. These investigations are still in progress, but the very definite results thus far secured on one phase of the problem, together with the urgent need of information on the subject, seem to justify the publication of the data already at hand. The method, the results of which are contained in this paper, is applicable only to open fields. Methods of dealing with this pest in roadways, on ditch banks, and along the rights of way of railroads will be discussed in a later publication.

W. J. Spillman, *Agrostologist.*

Office of Grass and Forage Plant Investigations,

Washington, D. C., March 17, 1905.

variation in the methods occurring in connection with the different cropping systems followed on the different plats.

CHARACTER OF THE SOIL.

The land on which these experiments were conducted consisted partly of heavy, dark-colored alluvial soil, inclined to be wet. The south end of the plats extended to a lighter type of soil of medium character. The results were practically the same on the two types of soil. This land had been abandoned to Johnson grass for some years and was in the middle of a large field which was badly infested and in which cotton had been grown for some years. At the time these experiments were undertaken it was believed by many that the eradication of Johnson grass was impracticable on account of the cost; but since that time the writer has learned of many farmers who have completely rid their farms of this pest by methods quite similar to those used in these experiments. Methods radically different from these have also been reported to be completely successful, though the writer has no personal knowledge to substantiate the claims made for the various methods.

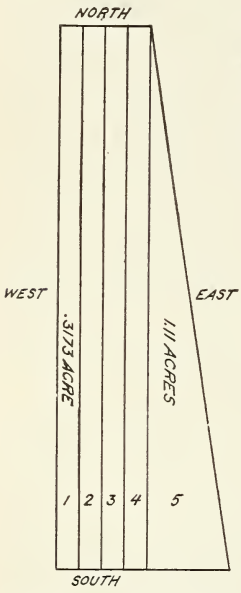


FIG. 1.—Diagram of experimental plats on the farm of Mr. J. B. Gay, Columbus, Tex.

METHODS OF TREATMENT.

The various methods of treatment will be considered in the order of their effectiveness. Figure 1 shows a diagram of the plats upon which the experiments were conducted. The general plan of the experiments was as follows: Plats 1 and 2 were devoted to rye and barley, respectively, during the winter, cowpeas the first summer, cereals again the next winter, and cotton the second summer. Plat 3 was devoted to cotton both years. Plat 4 was left bare the first year and devoted to cotton the second year. The triangular plat on the east side of the field, plat 5 in the diagram, was left in Johnson grass for the sake of comparison.

The preliminary treatment of plats 1, 2, 3, and 4 was identical and was as follows: In August, 1902, these plats were plowed with a disk plow to a depth of 4 or 5 inches. At this time the ground was dry and hard and a considerable growth of Johnson grass on the plats was turned under. On September 2, no rain having intervened, an attempt was made to remove the Johnson grass rootstocks from the ground by means of the implement shown in figure 2, here called a root digger, but called by the manufacturers a grass hoe. On account of the cloddy condition of the soil the root digger failed to do satis-

factory work. On the 15th and 16th of October, after the land had received sufficient rain to put it in good condition, it was replowed with a two-horse turning plow to a depth of about 4 inches, the utmost care being used to cut and turn every inch of soil in order that no Johnson grass roots might remain uncut. This plowing left the land in excellent condition. On the next day the root digger was used on this land, first crosswise of the furrows and then lengthwise. It is estimated that this operation removed fully 90 per cent of the Johnson grass roots from the soil and left them on the surface. They were then raked off with an ordinary horserake and removed from the land. On October 20, plat 1 was sown to rye and plat 2 to barley, plats 3 and 4 being left bare during the winter. The winter season proved to be very wet and neither the rye nor the barley made sufficient growth to justify cutting for hay in the spring. On April 7, 1903, all four of these plats were plowed again with a two-horse turning plow, the rye and barley on plats 1 and 2 being turned under.

The treatment given each of the plats will now be taken up separately. As the treatment given plat 4 resulted in the complete eradication of the grass, that will be described first.

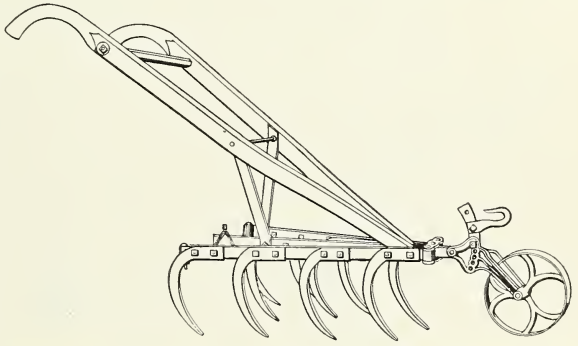


FIG. 2.—Root digger (so-called grass hoe) used in the experiments.

As previously stated, plat 4 had been plowed twice the previous autumn and treated twice with the root digger. It was again plowed on April 7. On May 4 a drag harrow was run over it. On May 18 it was run over with an ordinary heel-scrape, or heel-sweep, as it is called in many parts of the South. The implement used is shown in figure 3, an implement which shaves off an inch or two of the surface of the soil. The ground was harrowed again with an ordinary drag harrow the same day. The heel-scrape was run over the land again on July 17 and again on August 31. After that date no Johnson grass appeared on this plat. The subsequent treatment of the plat consisted of harrowing, on October 26, merely to smooth the surface.

In November, 1903, when the writer visited these plats, there was not a sprig of Johnson grass on plat 4, and Mr. Gay stated that none had appeared since the last of August. Plate I, figure 1, shows the appearance of this plat on November 24, 1903, just after it had been

laid off for cabbages. To the right of the plat will be seen the original Johnson grass sod, while to the left is the cotton grown on plat 3 during the summer of 1903. The grass roots shown are those of Colorado grass and not of Johnson grass.

On account of the unfavorable season, cabbages were not planted on plat 4, as contemplated in 1903, and the plat remained bare during the winter. During the summer of 1904 this plat was devoted to cotton. It was plowed on March 29 with an ordinary turning plow and cotton was planted the same day. This cotton was cultivated with the heel-sweep on April 20, at which time about half a dozen sprigs of Johnson grass were found along the eastern margin next the Johnson grass sod. On May 24 the heel-scrape was again used, on June 16 the cotton was chopped, on June 28 it was plowed again with the scrape, the final cultivation with the scrape being made on July 15. The cotton on this plat grew very rank, so much so, in fact, that it shed a great many of its bolls. In addition, the boll weevil destroyed a very large portion of the crop, so that the yield of cotton was only one-fourth of a bale per acre. Plate I, figure 2, shows the condition of this plat on August 29, 1904, just two years from the time the experiments began. It is seen that the growth of the cotton was very rank, no Johnson grass being present. As heretofore stated, there were a few sprigs of Johnson grass on this plat, but they were along the east side, adjacent to the Johnson grass sod, and were probably due to invading roots from the old sod.

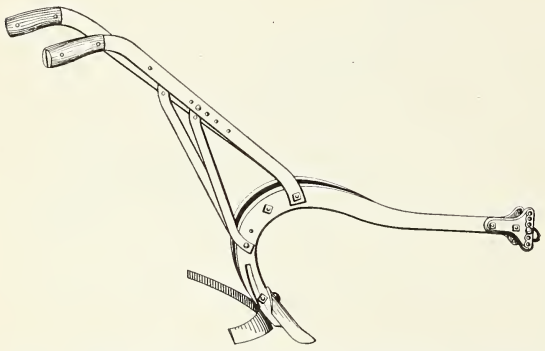


FIG. 3.—Stock, with shovel point and heel-sweep attached.

It will be seen that the summer-fallowing given this plat during the summer of 1903, added to the work of the root digger in the autumn of 1902, completely exterminated the grass by the last of August. The number of cultivations given this plat during 1903 included one plowing with the turning plow in the spring and the use of the heel-scrape once in the middle of May, again the middle of July, and again the last of August. It would, of course, be impracticable for a farmer to treat his whole farm by this method during a single season. The method, however, is entirely practicable if a small portion of the farm is treated each year and great care used not to allow Johnson grass to start again from seed on the portion of the farm that has already been cleared.

The next most successful treatment was that given plat 3. The roots were dug on this plat in the autumn of 1902, just as on plat 4, and plat 3 remained bare during the winter. In the summer of 1903 this plat was devoted to cotton. The land was plowed with a two-horse turning plow on April 7. On May 4 a drag harrow was run over it, and on May 18 it was planted to cotton. The cotton was chopped first on June 25, and was cultivated with the heel-scrape on June 26 and again on July 15. It was chopped again on July 23 and August 17. The last cultivation with the scrape was given on August 31. Although the weevil was very bad, the yield of cotton was one-third of a bale per acre. Plate II, figure 1, shows the condition of this plat on November 24. The same plat was devoted to cotton again during the summer of 1904, and no more Johnson grass was visible than may be seen in Plate I, figure 1, from a photograph taken the year before. On this plat, in addition to the cultivation above mentioned, bunches of Johnson grass, as they appeared, were removed by hand before the growth had reached a height of 6 inches. This was very easy, since all of the sprouts that came were either from seed or from short pieces of roots left in the soil by the root digger.

From the experience with this plat it seems that it would be entirely feasible to eradicate Johnson grass completely in a single year in the following manner: First, in the autumn, at a time when the land is in good condition to cultivate, plow to a moderate depth with a turning plow, being careful to cut and turn every inch of soil. A good disk plow so set as to cut every inch of the soil would answer as well. Harrow the land immediately so as to get it smooth and well pulverized. It is perfectly useless to try to use the root digger unless the land is brought into excellent condition and is free from clods. The next treatment is to run over the land with some implement which acts on the same principle as the root digger shown in figure 2. First, run crosswise of the furrows and then lengthwise. The roots left on the surface by this treatment may either be removed from the field or left to decay during the winter. In the spring, plow the land again with the turning plow and then put it in cotton in the usual way and give the cotton ordinary good tillage. Pay no attention to the Johnson grass until the first sprigs get to be about 6 inches high, then go carefully over the land and pull out every bunch of Johnson grass visible. By doing this work carefully it will be possible to remove every sprig, root and branch, because the grass sprouts come from small loose pieces of roots in the soil. By repeating this operation, never allowing a sprig to get more than 6 inches high, the grass can be completely eradicated during the summer, and the amount of labor required will not be excessive. We have found that the treatment given in the autumn by the root digger leaves comparatively little to be done the next summer. This is probably the most practical method

for eradicating the grass on cotton farms. Similar methods could be pursued in a cornfield, but the average farmer in the South will not give a cornfield the attention given a cotton field. It is therefore recommended that where this method is used for exterminating Johnson grass, cotton be grown the summer after the root digger is used in the autumn.

Very good results could doubtless be obtained by using the root digger on well-prepared land in the spring instead of in the autumn, but if the work is done in the autumn the cold weather of winter will kill a large number of roots that would otherwise remain to be destroyed by hand work the next summer.

The treatment given plats 1 and 2 was not as successful as that given plats 3 and 4, yet very good results were obtained. As already stated, these two plats were treated with the root digger in the autumn of 1902, and were then sown to winter grain. The next summer they were cultivated in cowpeas, no particular attention being given to the grass. The next winter they were again devoted to winter grain, while the next summer—that is, the summer of 1904—they were planted in cotton. Plate II, figure 2, shows the condition of these two plats on August 29, 1904, two years after the treatment began. When it is considered that this land was pure Johnson grass sod at the beginning, it will be seen that after two years, with no special treatment except the use of the root digger the first autumn, the land was comparatively free from grass; in fact, there was not enough grass to interfere in the slightest with the production of the cotton crop. Plate III shows the condition of the cotton crop of one of Mr. Gay's tenants a few yards from these plats. A careful study of the picture will show a few stalks of cotton among the Johnson grass. This picture could be duplicated on many other farms on the Colorado River, in the vicinity of Columbus, Tex. The principal difference in the treatment given the crop shown in Plate III and that shown in Plate II, figure 1, was in the use of the root digger the autumn previous.

IMPLEMENTS USED.

While the implement shown in figure 2 removes Johnson grass roots from well-prepared soil very effectively, the implement itself is an impracticable one. In the first place it is too small, and it therefore requires too much labor to treat the land. In the second place, the teeth soon clog with the roots and it is necessary to stop and raise the implement high enough to allow the roots to drop off and then start the team and hold the implement in the air until it has passed over the pile of roots. For the past year most of our energies have been directed to securing a more satisfactory implement for removing the roots from the soil. We have found that the teeth of the implement must be close enough together not to leave a space over 3 inches wide

between the tracks of the teeth. At the same time, when these teeth are all placed in one row, they bank up the soil in front of them and do not allow the implement to pass through properly. On loose, sandy soil the teeth in the same row must be at least 6 inches apart; on ordinary loam soil, 9 inches; and it is probable that on heavy clay soil they would have to be a foot apart. From plans furnished by Mr. Gay the implement shown in figure 4 was constructed. This implement has two rows of teeth so set that when viewed from the rear the teeth are only 4½ inches apart, but it did not remove the roots from the soil nearly so completely as did the grass hoe (fig. 2). We are now constructing a new form of the implement shown in figure 4, having three rows of teeth, those in the same row being 9 inches apart, and the rows so set that the teeth make tracks only 3 inches apart. As soon as a practicable implement has been evolved the details of its construction will be made public. The roots collected by the teeth of the root digger are easily dumped by tilting the implement on end, first one way and then the other. The tilting may be done by means of the handles without stopping the team.

In the course of these investigations several different types of machines have been constructed and tried. One of these was constructed on the principle of the ordinary sulky hayrake, but having rigid steel teeth so set as to draw into the loose soil about 4 inches deep. The amount of labor involved in working this machine seems to render it impracticable; besides, it would be quite expensive. We are endeavoring to evolve an implement that can be constructed by any local smith. It is probable that a heavy drag harrow could be made to take the place of a root digger such as that used in these experiments. While it would not remove the roots from the soil so completely as the root digger and would therefore leave more hand work to be done the next summer, nevertheless it is believed it would be practicable to eradicate Johnson grass in this manner.

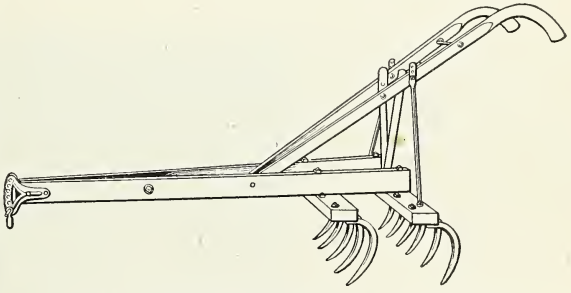


FIG. 4.—Root digger devised by Mr. J. B. Gay.

It is of course well known that Johnson grass can be eradicated by repeatedly plowing the land with a disk plow or a turning plow, but repeated plowing without the production of a crop is an expensive method of destroying the pest. By plowing in winter, thus leaving a

large proportion of the roots exposed to cold weather, the stand of the grass can be reduced very materially.

THE PRODUCTION OF HAY.

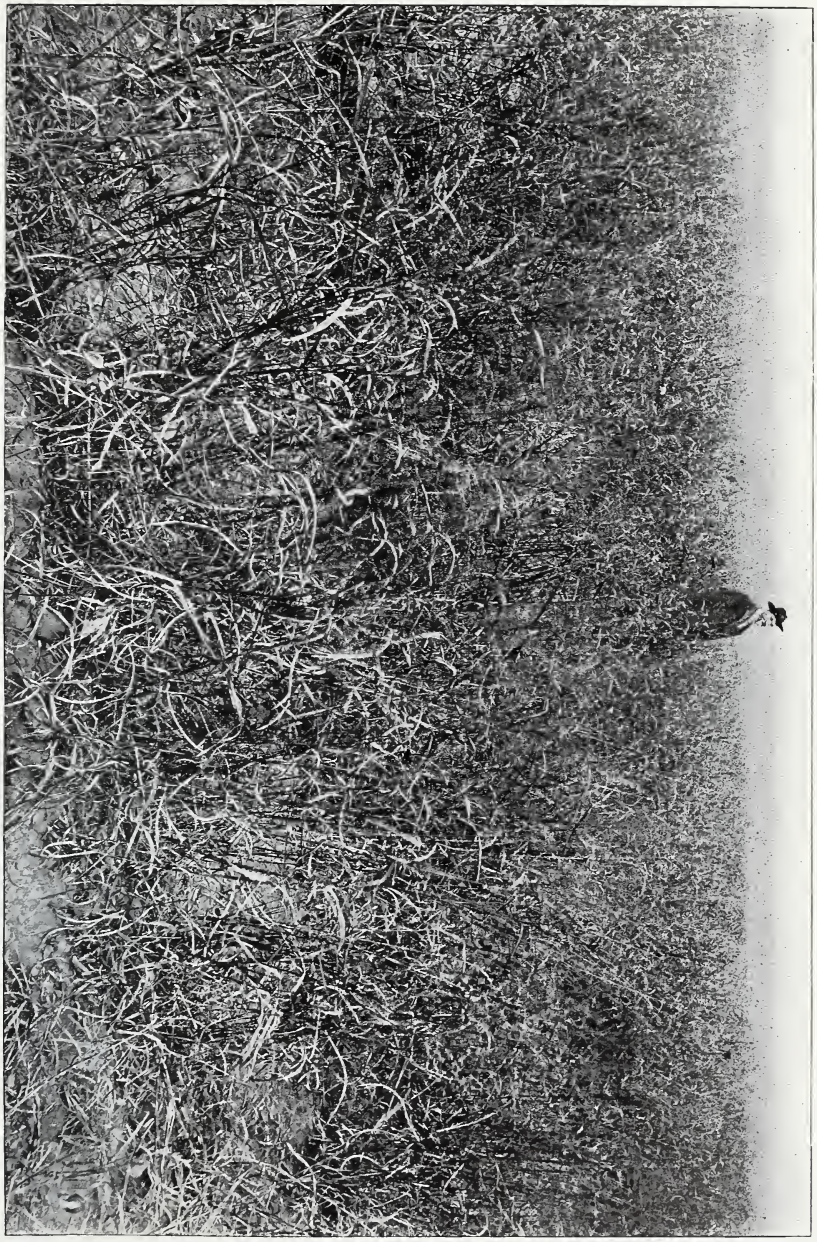
It is the writer's belief that, with the adoption of thoroughly modern methods of tillage throughout the Johnson grass region, it may become practicable to utilize this grass for the production of hay without serious interference with the cultivation of other crops. Fall plowing, treatment with a root digger, or perhaps with a heavy spike-tooth harrow, combined with more or less hand pulling the next season, will so reduce the stand of grass that it will be several years before it will again seriously interfere with the production of cultivated crops. The land can then be allowed to go back to Johnson grass for two or three years for the purpose of hay production, thus adapting it to a rotation of five or six years. The writer, however, would not advise any farmer to sow Johnson grass on land that is free from it until more is known about methods of controlling it. It is very unfortunate that a grass which will produce three good crops of hay in an ordinary season should be so hard to control as to render it a very serious pest.

FIG. 1.—PLAT 4 ON NOVEMBER 24, 1903; JOHNSON GRASS SOD TO THE RIGHT.

FIG. 2.—PLAT 4 ON AUGUST 29, 1904, TWO YEARS AFTER TREATMENT.

FIG. 1.—PLAT 3 ON NOVEMBER 24, 1903.

FIG. 2.—PLAT 1 ON AUGUST 29, 1904, TWO YEARS AFTER FIRST TREATMENT.



FIELD OF COTTON A FEW YARDS FROM THE EXPERIMENTAL PLATS.

IV.—INOCULATION OF SOIL WITH NITROGEN-FIXING BACTERIA.

By A. F. Woods, *Acting Chief of the Bureau of Plant Industry.*

INTRODUCTION.

The publication of the results obtained with pure cultures in inoculating leguminous plants has resulted in a very great demand being made upon the Department of Agriculture for inoculating material. The distribution made during 1904 was for the purpose of obtaining a large number of tests of the method under average farm conditions, and it was impossible to anticipate the demand which has arisen this spring (1905), the total quantity prepared for spring distribution having been promised early in February. It is expected, however, that this fall and next spring a further distribution will be made as far as our limited facilities will permit. Statements to the effect that the Department has stopped the distribution of these cultures are therefore erroneous. Applications for future distributions should state what legume is to be sown, time of sowing, and quantity of seed to be treated.

THE COMMERCIAL PRODUCTION OF CULTURES.

The patent which the Department of Agriculture holds upon the method of growing and distributing these organisms was taken out in such a way that no one can maintain a monopoly of the manufacture of such cultures. It is held in the name of Dr. George T. Moore, who developed and perfected the method, as described in former publications. Upon application the Department furnishes without discrimination all necessary information, and as far as possible "starting" or foundation cultures, to the bacteriologists representing experiment stations and commercial concerns which claim to be properly equipped, but it does not in any way guarantee their product. It is not likely that persons without expert knowledge can successfully multiply cultures of these organisms for sale or distribution, and it is understood that any cultures furnished are to be treated according to the methods devised by the Department.

Before experimenting with any bacterial preparations for legumes,

the farmer should study thoroughly the soil conditions under which the use of cultures offers any possibility of gain.[a]

Briefly, these conditions may be summed up as follows:

WHEN INOCULATION IS NECESSARY.

Inoculation is necessary—

(1) On a soil low in organic matter that has not previously borne leguminous crops.

(2) If the legumes previously grown on the same land were devoid of nodules, or "nitrogen knots," showing the need for supplying the nodule-forming bacteria.

(3) When the legume to be sown belongs to a species not closely related to one previously grown on the same soil. For instance, soil in which red clover forms nodules will often fail to produce nodules on alfalfa when sown with alfalfa for the first time.

WHEN INOCULATION MAY PROVE ADVANTAGEOUS.

Inoculation may prove advantageous—

(1) When the soil produces a sickly growth of legumes, even though their roots show some nodules.

If the cultures introduced are of the highest virility, their use will often result in a more vigorous growth.

(2) When a leguminous crop already sown has made a stand, but gives evidence of failing, due to the absence of root nodules.

The use of the culture liquid as a spray or by mixture with soil and top-dressing may save the stand if other conditions are favorable.

WHEN INOCULATION IS UNNECESSARY.

On the other hand, *inoculation is unnecessary and offers little prospect of gain*—

(1) Where the leguminous crops usually grown are producing up to the average and the roots show nodules in normal abundance.

Cultures of nitrogen-fixing bacteria are not to be regarded in the light of fertilizers, increasing yields under all average conditions. They do not contain the nitrogen itself, but the bacteria make it possible for the legumes to secure nitrogen from the air (through the formation of root nodules), and where the soil is already adequately supplied with these bacteria it will not usually pay to practice any form of artificial inoculation.

(2) When the soil is already rich in nitrogen.

It is neither necessary nor profitable to inoculate a soil rich in nitrogen when sowing legumes. Not only does the available nitrogen in

[a] Fully described in Farmers' Bulletin No. 214 of the Department of Agriculture, which will be sent without cost upon application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture.

the soil render the formation of nodules less necessary, but nitrogenous materials in the soil largely prevent the bacteria from forming nodules.

Any increased virility in nitrogen-fixing power possessed by any types of bacteria yet distributed may be rapidly lost in a soil containing an abundance of nitrogen, because the bacteria are rapidly multiplying in a medium in which there is no premium on vigor in securing atmospheric nitrogen.

WHEN FAILURE IS TO BE EXPECTED.

Inoculation will fail where other conditions (aside from the need of bacteria) are not taken into account, as the following:

(1) In soil that is acid and in need of lime.

Liming to correct acidity is as important for the proper activity of the bacteria as for the growth of the plants.

(2) In soil that responds in a marked way to fertilizers, such as potash, phosphoric acid, or lime.

The activity of the bacteria in securing nitrogen from the air and rendering it available to the legumes does not do away with the need for such fertilizing elements as potash and phosphorus.

(3) It must also be remembered that *inoculation does not "act like magic;"* it will not overcome results due to bad seed, improper preparation and cultivation of ground, and decidedly adverse conditions of weather or climate.

In the use of cultures, also, failure is almost certain where the directions are not carefully studied and intelligently followed.

(4) As the physics, the chemistry, and the biology of soils are studied in the laboratory and by means of actual field-plot trials to determine yield and quality of crops and the effect of one crop on the following crops, the very great complexity of soil and farm management becomes more manifest.

The value of pure-bred bacteria, whether associated with the crop or existing independently in the soil, as is true of fertilizers, can not be predicted with certainty on any soil without trial. Success on similar near-by lands may be taken as good evidence. But, unlike fertilizers, bacteria should in time be so inexpensive that each farmer can afford to try them for each leguminous crop on each field or soil type on his farm. The methods of distributing in dried form and the easy methods of multiplying on the farm in sufficient quantities to inoculate fields will make it possible to have all fields inoculated at all times.

COST OF CULTURES.

The question of the proper price for the commercial product is causing considerable inquiry among prospective experimenters and is of importance. The expenses which a commercial concern must

necessarily meet, such as rent, heat, light, insurance, postage, advertising, etc., aside from laboratory assistance and clerical hire, make any comparison with the cost to the Government of similar cultures difficult. The statement that the cultures cost but a few cents an acre refers only to the raw materials which make up the package. It is more than probable that natural competition will considerably reduce the present valuation of the commercial product, and the wisdom of patenting the Department's methods to prevent the formation of a monopoly is already demonstrated.

INCREASING CULTURES.

We are receiving numerous requests from persons who have secured commercial cultures, as well as those sent out from the Department of Agriculture, for information as to the methods employed in producing a large quantity of liquid culture from the dry culture secured as a starter; that is, how to make an "acre culture" do for 25 or 100 acres. Such methods will give good results only when special precautions are taken, and on this account have not been generally recommended. The contaminations, such as yeasts, molds, etc., which are bound to occur to a greater or less extent, are apt to take possession of the culture solution in which the bacteria are being multiplied, and unless great care is taken in thoroughly sterilizing all utensils employed the resulting culture will have no beneficial effect. The extra time required to secure sufficient growth of bacteria in 10 gallons of solution from a dry culture originally intended to produce a 1-gallon liquid culture makes the risk from contamination much greater than where the dry culture is proportioned in size to the larger amount of solution. If a growth sufficient to cloud the solution takes place within two days, the chances of securing an efficient culture are much better than where a longer time is taken; so that the volume of solution prepared should never exceed the actual requirements of the occasion.

The following directions are based on making 10 gallons of liquid culture, sufficient to inoculate 20 bushels of seed. By a litle computation the directions may be adapted to 5 gallons or to any intermediate quantities.

PREPARING AND USING THE CULTURE SOLUTION.

To prepare the culture solution, first select the tub, bucket, or other vessel in which you wish to grow the bacteria. *Clean and scald it out thoroughly.* For making the culture solution, rain water that has been thoroughly boiled and allowed to cool is best, though any good drinking water will answer. Add to 10 gallons of water 12 ounces of either brown or granulated (preferably granulated) sugar, 1½ ounces

of potassium phosphate (monobasic), which can be obtained at any drug store, and one-sixteenth ounce (30 grains) of magnesium sulphate. Stir until dissolved, then carefully open the small package containing the bacteria-laden cotton and drop the cotton into the solution. Do not handle any more than is absolutely necessary. Cover the tub with a moist, clean cloth to protect from dust, mold spores, etc. Keep in a warm place, but never let the temperature rise above blood heat. After twenty-four hours add 6 ounces of ammonium phosphate and allow the mixture to stand for another twenty-four hours. The liquid should now be cloudy and ready for use; if sufficient growth has not taken place to bring about this cloudiness, further time should be given, not to exceed a few days.

To inoculate seed.—Use enough culture liquid to moisten the seed thoroughly—about one-half of a gallon per bushel. This inoculating may be done either in a tub or trough, or by sprinkling the culture liquid on the seed on a clean floor and stirring and turning the heaps of seed with shovels until all are thoroughly moistened. After inoculation the seed should be spread out in a clean, shady place until sufficiently dry to handle. If planting is not to be done at once, the seed must be thoroughly dried to prevent molding. In dry weather about 25 bushels can be dried in half a day on 300 square feet of floor space. To do this there must be several open windows or doors to allow a free circulation of air, and the seed must be frequently stirred with a lawn rake. The inoculated seed, if thoroughly dried, may usually be kept without deterioration for several months.

To inoculate soil.—Take enough dry earth or sand so that the solution will merely moisten it. The soil should be preferably from the field to be inoculated, so as to avoid spreading diseases or weeds. Mix thoroughly, so that all the particles of soil are moistened. Thoroughly mix this earth with four or five times as much; spread this inoculated soil thinly and evenly over the prepared ground exactly as if spreading fertilizer. The inoculated soil should be harrowed in immediately to protect the bacteria from sunlight. In using this method allow 1 gallon of the liquid culture to 4 acres or less.

Either of the methods described may be used, as may be most convenient.

To prevent any possible delay, the necessary chemicals should be ordered in advance. If the local druggist does not have them in stock, he can doubtless secure them within a reasonable time.

KEEPING CULTURES FOR FUTURE USE.

The question is frequently arising as to the possibility of the farmer's keeping over cultures from one year to another by soaking up a little of the liquid culture in cotton and drying this cotton. *This pro-*

posed practice is not to be advised in any case. Contaminations take place so readily, and once started spread so rapidly, that for assured good results it is absolutely necessary to start with a pure culture. The pure culture, moreover, can only be prepared by a trained bacteriologist with laboratory facilities. These cultures in the dry state will keep, under ordinary conditions, from six months to a year.

There is an additional reason, fully as important, which makes the above method impracticable. The cultivation of the bacteria for any considerable length of time in solutions containing ammonium salts rapidly lessens their infective power and their ability to gather nitrogen from the air, so that transfers or new cultures made with absorbent cotton from the cultures prepared for field use would contain organisms of reduced efficiency. It is partly owing to these factors that it is impracticable to distribute the bacteria in liquid cultures and maintain the requisite effectiveness.

In the use of cultures for inoculating soil the farmer should be guided, as in all other matters pertaining to soil treatment, by his own peculiar needs, and should not give too great weight to the experiences of others whose soil conditions may differ widely. *It would be unwise to invest largely in any new method for increasing plant growth, whether bacterial or of any other nature, without previously experimenting in a small way.*

DANGER OF INOCULATION BY SOIL TRANSFER.

Satisfactory inoculations have been obtained by transferring soil from old fields on which the legume has been grown, but experience has shown that there are dangers incident to such methods of soil transfer which it is wise to avoid.

The source of supply of such soil should be very definitely known, and in no case should soil be used from fields which have previously borne any crops affected with a fungous disease, a bacterial disease, or with nematodes. Where a rotation of crops is practiced, it is often difficult to make sure of this factor, so that the method of soil transfer is, under average circumstances, open to suspicion, if not to positive objection. Numerous animal and plant parasites live in the soil for years, and are already established in so many localities that it is manifestly unwise to ship soil indiscriminately from one portion of the country to another.

The bacterial diseases of the tomato, potato, and eggplant, and the club-root, brown-rot, and wilt disease of the cabbage, all more or less widely distributed, are readily transmitted in the soil, while in the South and West there are the wilt diseases of cotton, melons, sweet potatoes, cowpeas, and flax, and various nematoid and root-rot diseases which might easily become a serious menace over areas much

larger than they now occupy if deliberately spread by the careless use of soil for inoculation purposes. There are several insect and fungous diseases of clover to be avoided, and various diseases of beans and peas. There is also a disease of alfalfa, the "leaf spot," which is causing damage in some regions. These are only a few of many diseases liable to be transmitted in soils. The farmer should therefore be on his guard. The danger from such sources is by no means imaginary. The Department of Agriculture has had specific cases of such accidental distribution reported, and if the business of selling soil for inoculation is made to flourish by farmers purchasing without question "alfalfa soil," "cowpea soil," etc., there is every reason to believe that experience will demonstrate the folly of such haphazard methods.

Of scarcely less importance is the danger of disseminating noxious weeds and insect pests through this plan of inoculation by means of soils. Even though weeds may not have been serious in the first field, the great numbers of dormant seeds requiring but a slight change in surroundings to produce germination are always a menace. The enormous damage to crops caused by introduced insects and weeds should convey a warning and lead to caution. It is not the part of good judgment to view the risk as a slight one justified by the end in view.

PURE-CULTURE INOCULATION.

The extensive experiments carried on by the Department of Agriculture during 1904 demonstrated the fact that, by the proper use of pure cultures, the nodule bacteria are actually carried into the soil in such a way as to form root nodules, and where other conditions are favorable the inoculation thus brought about makes possible the growth of each legume in soils where it had previously failed from the lack of bacteria. The original cultures used, however, must be prepared with the utmost care and with a view to preserving and increasing the natural power of the bacteria as "nitrogen fixers" rather than merely to make them grow under favorable conditions. The methods devised in our Laboratory of Plant Physiology are based on well-recognized principles of plant breeding and selection, and mark a decided advance in the production of cultures for soil inoculation. The old pure-culture methods were not effective, for reasons clearly stated by Doctor Moore in Bulletin No. 71 of the Bureau of Plant Industry and by Doctor Moore and Mr. Robinson in Farmers' Bulletin No. 214.

The Department of Agriculture is continuing the work of developing types of the bacteria associated with leguminous plants, which will have greater activity, collecting from the air more nitrogen per acre than forms now common in nature or available from laboratories. It is desirable that similar investigations should be conducted with

reference to the nitrogen-fixing bacteria existing in the soil independent of the legumes. Important steps have already been taken along this line, but the very large demand for cultures for leguminous crops, by consuming the time of the laboratory force, has seriously retarded these investigations during the past year.

The Department is ready to cooperate with experiment stations and commercial firms, to give and to receive suggestions, to test the product of others, and to furnish, as far as possible, cultures to be tested in the laboratory and under field conditions.

There is nothing in the nature of the processes involved which would prevent a competent bacteriologist, after some experience in this particular field, from producing cultures of as high a grade as those sent out by the Department, and every assistance will be given to competent persons desiring to undertake the work.

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